New High Proper Motion Stars from the Digitized Sky Survey. II. Northern Stars with $0.5 < \mu < 2.0'' yr^{-1}$ at High Galactic Latitudes.[1]

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ABSTRACT

In a continuation of our systematic search for high proper motion stars in the Digitized Sky Survey, we have completed the analysis of northern sky fields at galactic latitudes above 25 degrees. With the help of our SUPERBLINK software, a powerful automated blink comparator developed by us, we have identified 1146 stars in the magnitude range $8 < r < 20$ with proper motions $0.500 < \mu < 2.000''$ yr^{-1}. These include 1080 stars previously listed in Luyten's proper motion catalogs (LHS, NLTT), 9 stars not previously listed in the Luyten catalogs but reported elsewhere in the literature (including 1 previously reported by our team), and 57 new objects reported here for the first time. This paper includes a list of positions, proper motions, magnitudes, and finder charts for all the new high proper motion stars. Combined with our previous study of low galactic latitude fields (see Paper I), our survey now covers over 98% of the northern sky. We conclude that the Luyten catalogs were $\simeq$90% complete in the northern sky for stars with $0.5 < \mu < 2.0''$ down to magnitude r=19. We discuss the incompleteness of the old Luyten proper motion survey, and estimate completeness limits for our new survey.

Subject headings: astrometry — surveys — stars: kinematics — solar neighborhood

1. Introduction

One of the main interests of large proper motion surveys is their use in identifying the low-luminosity stellar components of our Galaxy. Surveys of faint stars with large proper motions have traditionally been the most powerful means to identify intrinsically faint objects in the neighborhood of the Sun. In particular, the vast majority of all the known nearby red dwarfs, red subdwarfs, and white dwarfs, have first been identified as high proper motion stars.

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The most extensive catalogs of high proper motion stars are the two catalogs by W. H. Luyten, published over 20 years ago. The *LHS catalogue* (Luyten 1979) lists 3602 objects with estimated proper motions $\mu > 0.500'' \text{ yr}^{-1}$ and 867 other stars with estimated proper motions $0.235 < \mu < 0.500'' \text{ yr}^{-1}$. The NLTT catalogue (Luyten 1979) is essentially an extension of the LHS catalogs, and lists 58845 high proper motion stars, the majority of which have estimated proper motions $\mu \geq 0.18'' \text{ yr}^{-1}$. The vast majority of the ≈ 3000 solar neighborhood stars are listed as high proper motion stars in the Luyten catalogs. Furthermore, new nearby stars continue to be identified among LHS and NLTT stars, the majority of which still do not have any formal spectroscopic classification.

The LHS and NLTT catalogs are significantly incomplete in the Southern sky and at low galactic latitudes, leaving large expanses of the Solar neighborhood that still are very poorly surveyed for intrinsically faint stars. To remedy this, several new surveys of high proper motion stars are now being conducted on different parts of the sky. Most of the new, deep proper motion surveys are being conducted in the Southern sky. These include the Scholz *et al.* (2000) survey, the Calár-ESO proper motion survey (Ruiz *et al.* 2001), and the Liverpool-Edinburgh proper motion survey (Pokorny, Jones, & Hambly 2003). These surveys are all based on analysis of photographic plate material obtained from the 1970s to the 1990s (the United Kingdom Schmidt Telescope survey and the ESO-schmidt survey). Thus far, little attention has been directed toward the northern sky since the publication of the Luyten catalogs (Monet *et al.* 2000). However, the northern Palomar Observatory Sky Surveys (POSS) represent one of the most interesting opportunities for proper motion investigations. The first and second epoch surveys (the 1950s POSS-I, and the 1990s POSS-II) together provide a large baseline of 35-45 years which provides better sensitivity to high proper motion stars, and greater accuracy on proper motion measurements.

The USNO-B1.0 all-sky catalog, recently made available (Monet *et al.* 2003), constitutes a major achievement in the characterization of the largest possible number of objects detected in the large photographic surveys. The northern part of the catalog is based on scans of the POSS-I and POSS-II plates. Besides providing relatively good astrometry and optical photometry for an unprecedented number of stars, the USNO-B1.0 also tentatively lists proper motions, when detected. However, a recent analysis of the proper motions in the USNO-B1.0 by Gould (2003) shows that the USNO-B1.0 in its current form cannot be used to assemble a complete catalog of high proper motion stars. The proper motion errors in USNO-B1.0 are relatively large and many stars known to have large proper motions are not detected as such. For example, the USNO-B1.0 does not correctly identify as high proper motion objects more than 10% of the Luyten stars. Furthermore, the USNO-B1.0 is too liberal in it identification of moving objects, and contains some 200× too many high proper motion star entries, the vast majority of which are bogus detections.

We have been conducting an independent analysis of the Palomar Sky Surveys, using a more direct approach to the detection of high proper motion stars. The SUPERBLINK software, developed by one of us (SL), works like an automated blink comparator, and uses a difference method to identify variable and moving objects in pairs of sky images obtained at two different epochs (Lépine Shara, & Rich 2002)(- hereafter paper I). Our method has proved particularly successful in

finding moving objects in densely populated regions, areas that have traditionally been avoided in proper motion searches. Furthermore, every object identified by our code is assigned a probability of being real, and the best candidates are all confirmed visually by direct inspection of the DSS images. As a result, the number of bogus detections is extremely low.

In Paper I we have presented the results of a search at low galactic latitudes ($|b| < 25.0$) for stars with proper motions $0.5 < \mu < 2.0''$. Within a search area covering ≈9000 square degrees, we discovered 141 previously unreported high proper motion stars. In this paper, we extend our analysis to northern sky fields at higher galactic latitudes ($|b| > 25.0$). In §2, we briefly describe our identification methods and our assignment of magnitudes. §2 compares our survey with the Luyten proper motion catalogs. The new stars discovered in our surveys are presented in detail in §4. In §5 we use reduced proper motion diagrams to separate the high proper motion stars into three classes of objects. A summary and conclusions follow in §7.

2. Proper Motion Search and Identification

The method used for the identification of high proper motion stars from Digitized Sky Survey images is described in detail in Paper I. We provide here only a brief summary.

The survey is based on Digitized Sky Survey (DSS) scans of the first and second epoch Palomar Observatory Sky Survey (POSS-I, POSS-II) in the red. The area covered by the POSS-I plates is divided into a grid of 642,900 square subfields $17' \times 17'$ in size, with a $15'$ grid spacing allowing for a significant overlap. For each subfield, a pair of DSS images (POSS-I, POSS-II) is retrieved and analyzed with the SUPERBLINK software. The code performs a superposition of the two images by minimizing the residuals after shifting and rotating the POSS-II image onto the POSS-I grid. The POSS-II red image is also degraded to match the resolution and quality of the POSS-I red image. The SUPERBLINK software then uses search algorithm to identify and characterize the differences in the two images. Variable stars, plates defects, and moving objects are identified and cataloged. Finders charts of candidate high proper motion stars, in the form of $4.25' \times 4.25'$ dual-epoch images, are generate by the code. These can be blinked on the computer, and prospective objects are all confirmed by visual inspection.

Once the existences of high proper motion stars are confirmed visually, we search for counterparts of the objects in large astrometric and photometric catalogs. For the current sample of high galactic latitude, high proper motion stars, we used the USNO-B1.0 catalog (VizieR catalog I/284) to obtain optical, photographic magnitudes, and the 2MASS All-Sky Point Source Catalog (PSC) to get infrared magnitudes. Since the USNO-B1.0 catalog is based on the same plate material, we do find counterparts for the majority of our confirmed high proper motion stars, although a small number of confirmed objects are notlisted in the USNO-B1.0, for reasons that are unclear at this point. Likewise, we do also find 2MASS counterparts for the majority of our stars, but a small number of faint objects do not show up, most likely because they are not detected in the infrared.

To this date, a total of 623,474 subfields, or $\simeq$ 97% of the sky north of $\delta = -3.0°$, have been successfully processed with SUPERBLINK. Some 4,768 subfields ($\simeq 0.74\%$) were rejected by the code for a variety of reasons, including the presence in the subfield of a very bright (R$<$ 5) star, a large plate defect, or an extended, saturated object such as the Andromeda Galaxy. The remaining 14,658 fields from our grid that have not been processed yet are mainly fields at very high declinations ($\delta > +88.0$), which we avoided because of potential problems in superposition, and subfields near the low declination limit of the POSS-I plates ($-3.0 < \delta < -1.0$) which are not strictly part of the northern sky.

In the area north of δ=0.0° analyzed by SUPERBLINK, we have identified a total of 1797 stars with proper motions $0.500 < \mu < 2.000''$ yr^{-1}; 1146 at high galactic latitudes ($|b| > 25$), and 651 at low galactic latitudes ($|b| < 25$). We have obtained complete bri magnitudes from the USNO-B1.0 for 1691 of the stars. Partial information, i.e. a magnitude in at least one of the photographic bands, was obtained for 64 more stars. We were unable to find a counterpart in the USNO-B1.0 catalog for the 42 remaining objects, although they all clearly show up in the DSS. Whenever a star didn't have a counterpart in the USNO-B1.0 catalog in the r band, we used the r magnitude estimated by SUPERBLINK. Infrared JHK_s magnitudes were found in the 2MASS All-Sky PSC for 1754 of our high proper motion stars; the remaining 43 stars most probably are too faint in the infrared to have been detected by 2MASS.

To estimate the astrometric errors in the positions derived by SUPERBLINK, we compare with the quoted positions of the 2MASS counterparts. On output, SUPERBLINK gives the position of the star at the epoch 2000.0. Given the proper motion vector, we extrapolate the position of each star at the epoch of the 2MASS observations. The distribution of errors between the SUPERBLINK and 2MASS positions are shown in Figure 1. The positions of the 2MASS counterparts, as given by the 2MASS All-Sky PSC, are accurate to about $0.15''$ in both RA and DEC. Our distribution of the differences between our positions and the 2MASS positions suggests there is a mean error of $\approx 1.2''$ on the absolute positions estimated with SUPERBLINK. These are admittedly much less accurate than the positions quoted in the USNO-B1.0 catalog, which are supposed to be accurate to $0.2''$. However, our absolute positions are entirely dependent on the accuracy of the POSS-I plate solutions calculated for the DSS, which we are using. Because we are shifting and degrading the POSS-II DSS image to superpose it on the POSS-I DSS image, we effectively lose much of the information provided by the superior POSS-II plates to determine absolute positions. In addition, most of the stars for which the SUPERBLINK absolute positions have errors $> 2''$ are relatively bright objects ($r < 14$) that have a saturated core on the POSS-I and POSS-II plates, and whose absolute position cannot be determined very accurately using the SUPERBLINK algorithms.

Actually, SUPERBLINK has been specifically designed to measure *relative proper motions* between two images, and not the absolute position of the stars. The relative position of a moving star between the POSS-I and POSS-II images is generally calculated to better than 0.4 arcsec, which yields an accuracy on the proper motion better than $0.01''$ yr^{-1}. This can be verified by comparing the proper motions calculated for the LHS stars by SUPERBLINK with the proper

motions given in the USNO-B1.0 catalog. The USNO-B1.0 catalog lists reasonably accurate proper motions for $\approx$ 85% of the 1199 high proper motion stars identified with SUPERBLINK at high galactic latitudes. The other 15% of the stars have proper motions quoted in the USNO-B1.0 that are clearly inaccurate, and most of them are actually listed as not having any measurable proper motion. Figure 2 shows the distribution of the difference between the proper motions estimated with SUPERBLINK, and those given in the USNO-B1.0 catalog. The difference is generally smaller than $\pm0.01''$ yr^{-1}, which confirms our estimates of the proper motion errors from SUPERBLINK. The proper motion errors quoted in the USNO-B1.0 catalog are often much larger than $0.01''$ yr^{-1}, and the "wings" of the distribution in Figure 2, extending beyond $\pm0.01''$ yr^{-1}, correspond to those stars with larger proper motion errors in the USNO-B1.0 catalog. There also appears to be a systematic difference of $0.004''$ yr^{-1} in the proper motions measured in declination by SUPERBLINK and those listed in the USNO-B1.0. The source of this systematic difference is unclear at this point, but in any case it is smaller than our adopted error of $\pm0.01''$ yr^{-1} for the relative proper motions measured by SUPERBLINK.

3. Comparison with the Luyten proper motion catalogs

We have cross-correlated the list of high proper motion stars identified with SUPERBLINK with a list of objects comprising all stars listed in the two main Luyten catalogs (LHS, NLTT). Overall, 1593 of the 1797 stars recovered by SUPERBLINK were matched to stars listed in the Luyten catalogs. This left 204 stars not listed in the LHS or NLTT catalog. Some 138 of those stars were found at low galactic latitudes ($|b| < 25.0$) and have already been presented in Paper I. The remaining 66 new high proper motion stars, found at higher galactic latitudes, are presented in §4 below.

Our software also recorded 111 more stars, which we found to have proper motions in the range $0.300 < \mu < 0.500''$ yr^{-1}, but which were matches to stars listed in the Luyten catalogs as having $\mu > 0.500''$ yr^{-1}. Likewise, 56 of the stars found by SUPERBLINK with $\mu > 0.500''$ yr^{-1} were listed in the LHS or NLTT catalog as stars with proper motions $0.420 < \mu < 0.500''$ yr^{-1}. This expected blurring near the survey cutoff is the result of proper motion errors in both Luyten's and in our own survey.

On the other hand, there are a number of northern stars listed in the Luyten catalogs as having $\mu > 0.5''$ yr^{-1} that SUPERBLINK did not recover. These include 33 stars with proper motions larger than the upper limit of our survey ($\mu > 2.0''$ yr^{-1}), which our code could not possibly have recovered and are thus not considered true "misses". Another 10 Luyten stars were in subfields rejected by SUPERBLINK (see §2). There are another 19 stars that are listed individually in the Luyten catalog but are actually closer companions to brighter stars, and are unresolved on the POSS plates. In all cases, our software either did identify at least the primary star correctly, or the unresolved pair was identified as a single moving object. We do not now consider these as true "misses" either since at least the stellar system was correctly identified. In our Paper I

analysis, however, we happened to count these stars as true misses, which at the time gave the impression that SUPERBLINK somehow had problems identifying moving stars in the $11 < r < 13$ magnitude range; this is not the case. It is a fact, however, that SUPERBLINK systematically misses all stars brighter than $r = 8$, and misses a significant fraction of stars in the magnitude range $9 < r < 11$. On the DSS images, these very bright stars appear as very saturated, extended objects with diffraction spikes and halos. These are not processed very efficiently by the code, and most are simply rejected. Thus, there were 245 very bright Luyten stars ($r < 11$) that were missed by our code.

Finally, there were 11 faint ($12.7 < r < 19.2$) Luyten stars that SUPERBLINK did not recover. We were completely unable to find 4 of these stars (LHS1657, LHS1986, NLTT22764, NLTT11999) even by direct visual inspection of the DSS images, and we suspect these might be bogus. The other 7 faint high proper motion stars missed by SUPERBLINK were found by visual inspection of the DSS images. The software missed those for reasons that are not entirely clear, but all those objects happen to be in the proximity of a brighter star on at least one of the POSS images, which might explain why the software had trouble locating them.

The new, updated distribution of northern stars with $0.5 < \mu < 2.0''$ yr^{-1} as a function of magnitude is shown in Figure 3. It is compared to the old distribution based on the LHS catalog. The peak of the distribution has shifted very little towards fainter magnitudes and has stayed around $r = 14$. While there are now significantly more faint high proper motion stars known, there still appear to be a sharp drop beyond $r = 18$. The high success rate of SUPERBLINK for the identification of $r = 18$ high proper motion stars strongly suggests that this feature is real, and that if any $r = 19$ stars have been missed by SUPERBLINK, there should be very few of them.

We are now in a position to directly determine the completeness of the LHS catalog for the northern sky. Figure 4 plots the completeness of the LHS catalog as a function of magnitude, in the assumption that the census of high proper motion stars in the northern sky is now complete. The figure shows that the LHS catalog was complete down to r=12. Then the completeness dropped steadily, to fall below 50% for stars with r=18. Overall, the LHS catalog was about 90% complete for stars down to r=19, as was correctly estimated by Monet *et al.* (2000). At this point, however, the question of the completeness of the LHS catalog becomes of purely historical interest, since our proper motion survey now clearly supersedes Luyten's for the northern sky.

4. Estimated completeness of our survey

Our recovery rate of Luyten stars as a function of magnitude is plotted in Figure 5. Overall, the success rate for the recovery of Luyten stars exceeds 99.5% in the magnitude range $11 < r < 19$. In high galactic latitude fields, stars appear as isolated objects most of the time, and are picked out very easily by the code. The fact that the very few Luyten stars that SUPERBLINK missed were are in the vicinity of brighter objects, suggest that proximity to a brighter star must indeed

be responsible for most of the non-detections. For a star to be missed by SUPERBLINK, it has to be blended with a brighter object in both the first and the second epoch. The chance for this to occur depends on the local stellar density in the field, which means that most of the stars missed by SUPERBLINK must reside in low galactic latitude fields. The chance of a non-detection also depends on the magnitude of the star, since it is easier for a fainter star to hide in a crowded field than for a very bright star. For similar reasons, the Luyten catalog was significantly more incomplete at low galactic latitudes.

At high galactic latitude, the probability of a chance alignment with a brighter star at *both* the POSS-I and POSS-II images is very small ($< 1\%$). Hence we are confident that SUPERBLINK probably detected 99% of the high proper motion stars down to at least $r = 18$. Our main concern is with the crowded, low galactic latitude fields, where chance alignments are much more common, and where the probability of a non-detection is much larger.

A simple way to test the effects of crowding on the detection of high proper motion stars is to compare the number of stars detected at high and low galactic latitudes. A sample of high proper motion stars selected above a fixed threshold (in our case $\mu > 0.5''$ yr^{-1}) is not expected to be distributed uniformly across the sky. Disk stars toward the apex and antapex tend to have smaller proper motions than those lying in a direction perpendicular to the Sun's motion. Since the apex is at $b \simeq 23^\circ$, we do expect to find fewer high proper motion, disk stars at low galactic latitudes. Halo stars also have an asymmetric motion on the sky, and those halo stars in the direction of galactic rotation and antirotation are expected to show smaller proper motions. Again, this results in a smaller number of stars, above the proper motion cutoff, that will be found at low galactic latitudes. On the other hand, if $N_{b>25}(r)$ is the number of stars of magnitude r found at $|b| > 25$, and if $N_{b<25}(r)$ is the number of stars of magnitude r found at $|b| > 25$, then we expect the ratio $N_{b<25}(r)/N_{b>25}(r)$ to be approximately constant. Since the detection of stars in crowded fields depends on the magnitude of the star, incompleteness will show up as a deficit of fainter stars in low galactic latitude fields.

This test is illustrated in Figure 6. The expected ratio value of the constant $N_{b<25}(r)/N_{b>25}(r)$ is determined using the brighter stars ($10 < r < 14$). For both the Luyten catalog and our survey, this ratio is $N_{b<25}(r)/N_{b>25}(r) \simeq 0.58$. The ratio is smaller than what one would expect for a *uniform* distribution of stars over the sky (0.732), which shows that our concern about expecting fewer stars with $\mu > 0.5''$ yr^{-1} at low galactic latitudes was justified. What Figure 6 reveals, however, is the significant incompleteness of the Luyten catalogs for stars $r = 15$ and fainter. The error bars denote Poisson statistics errors. The value of the ratio provides a reasonable estimate of the completeness at low galactic latitude, provided that the completeness at high galactic latitude is high. Hence, the larger ratio in the last magnitude bin $r = 19$ in Figure 6 is not significant since the census is probably incomplete at large galactic latitudes. However, both the Luyten survey and our own survey are significantly complete at high galactic latitudes down to $r = 18$, and hence Figure 6 provides a reasonable means to estimate the completeness at low galactic latitudes.

Luyten's census appears to be only 50% complete at $|b| < 25$ for stars between $r = 15$ and $r = 18$. Our survey, on the other hand, seems to have recovered most of the missing stars, and appears to be significantly complete all the way down to $r = 17$. There is marginal evidence for some missing stars at $r = 15$, but the fact that the ratio at $r = 16$ and $r = 17$ is close to the expected value suggests that this is probably a statistical fluke. On the other hand, there is a significant lack of stars in the $r = 18$ magnitude bin. Assuming that our survey is 99% complete at high galactic latitudes down to $r = 18$, then we are possibly still missing $\approx 40\%$ of $r = 18$ stars at low galactic latitudes, which is about 9 stars.

5. New high proper motion stars discovered by SUPERBLINK

5.1. Stars reported elsewhere in the literature.

We identified 66 new high proper motion stars with $\mu > 0.5''$ yr^{-1} that are not listed in the Luyten catalogs. Upon verification, we found that 9 of these had been previously reported in the literature. These stars are listed in Table 1. Here is a short description of how these stars were previously discovered.

5.1.1. LSR1000+3155

This star is the faint companion to the bright nearby G star HD86728 (GJ376), discovered by Gizis *et al.* (2000a) from 2MASS data. The companion is an old, metal-rich M6.5 red dwarf. The system is at a distance of 14.9 pc.

5.1.2. LSR1311+2923

This is the star GSC2U J131147.2+292348, identified in a proper motion survey for cool white dwarfs near the north galactic pole (Carollo *et al.* 2002). It is a peculiar, carbon rich DQ white dwarf. Carollo *et al.* (2002) computed the proper motion of the star using 6 photographic plates obtained at different epochs, and found a proper motion $0.477{\pm}0.005''$ yr^{-1}. This is significantly smaller than our $0.505''$ yr^{-1}, and requires further investigation. While Carollo *et al.* (2002) cites calculated proper motions $[\mu_{RA}, \mu_{decl}] = [-0.382 \pm 0.002, 0.286 \pm 0.005]''$ yr^{-1}, SUPERBLINK finds $[\mu_{RA}, \mu_{decl}] = [-0.374 \pm 0.010, 0.340 \pm 0.010]''$ yr^{-1}, which shows that the discrepancy arises only in the determination of μ_{decl}. For comparison, we looked for the proper motion of that star in the USNO-B1.0 catalog. The USNO-B1.0 quotes this star as having proper motion components $[\mu_{RA}, \mu_{decl}] = [-0.380 \pm 0.004, 0.332 \pm 0.003]''$ yr^{-1} which fall within the range of values estimated by SUPERBLINK. We therefore suspect that it is the value of μ_{decl} given by Carollo *et al.* (2002) that is probably in error.

5.1.3. LSR1403+3007

This is the star 2MASSW J1403223+300755, discovered by Gizis *et al.* (2000b) in an survey for very cool objects based on large infrared to optical colors. The star is an M8.5 dwarf at a probable distance d$\simeq$21.4pc.

5.1.4. LSR1425+7102

This star was discovered by us with our SUPERBLINK code, and was presented in a previous paper (Lépine, Shara, & Rich 2003). It is the first known representative of a type of ultra-cool subdwarf (spectral type sdM8.0).

5.1.5. LSR1524+2925

This is the cool star 2MASS J1524248+292535, identified in the Two Micron All Sky Survey database from its large infrared to optical color (Reid *et al.* 2002). The star is a nearby M7.5 dwarf, at a distance of about 15pc.

5.1.6. LSR1530+5608AB

This common proper motion binary system is composed of the stars J153055.62+560856.2 and J153055.62+560856.4. These stars were first identified as a proper motion pair by Monet *et al.* (2000), in a survey for faint high proper motion stars using extra POSS II plates. Spectroscopy shows both stars to be extreme subdwarfs. Although Monet *et al.* (2000) do not specify the spectral subtypes of the stars, an examination of their published Keck II spectrum suggest that LSR1530+5608A (=J153055.62+560856.2) is an esdM3.5, while LSR1530+5608B (=J153055.62+560856.4) is an esdM4.0. Following the spectral type to absolute magnitude relationships defined in Lépine, Rich, & Shara (2003), this places the system at a distance of about 100pc, and suggests a transverse velocity $V_t \approx 240$ km s^{-1}, consistent with the pair being a member of the Galactic halo.

5.1.7. LSR1615+3151

Although we found a reference to this star in the literature, it is here identified as a high proper motion object for the first time. This is the star CLS 100, identified as an M dwarf by Sanduleak & Pesch (1988), in an objective-prism survey. Very little information exists on this object. The absence of this star from the Luyten catalogs comes as a surprise, since this star is relatively bright (r=14) and does not lie in an especially crowded field.

5.2. Stars reported for the first time.

We present in Table 2 a set of 57 new stars with proper motion larger than $0.5'' \text{ yr}^{-1}$. A search on Simbad confirms that none of these stars has ever been mentioned in the literature before. Finder charts for all the objects can be found in the Appendix. More than half of the new high proper motion stars are relatively faint ($17 < r < 19$) objects. Such faint stars were relatively difficult to find with Luyten's methods, which explains why they were missed.

On the other hand, our list of new high proper motion stars does includes 24 objects with photographic red magnitude r=16 or brighter. Such bright objects should be relatively easy to find, which raises questions as to how they were missed by Luyten. One notices that, while LSR0848+0856 has a red magnitude $r = 13.6$, it stands very close to the 9th magnitude star BD+09°2058 in the POSS-I image (it actually falls on one of the diffraction spikes). This might explain why it was missed by Luyten. The image of the $r = 14.8$ star LSR0959+1739 is partially merged with that of another bright star on the POSS-I plate, which also makes its identification difficult; merged images of two or more stars tend to be identified as "non-stellar" by plate measurement scanners. LSR0150+0900 is also "merged" with another bright star on the POSS-I image, as are LSR1122+4809, LSR1302+3340, LSR1442+3255, LSR1604+0904, LSR1746+6953, and LSR2204+1505, while LSR1033+2559 comes very close to being merged with another star. LSR1421+4952, on the other hand, is partially merged with the image of a background galaxy. Since Luyten used the POSS-I survey as his first epoch, it thus clearly appears that proximity to a bright object was the main source of incompleteness for bright, high proper motion stars in the Luyten survey. Close examination also reveals that LSR0923+1817 and LSR1340+1902, while showing up as well-isolated objects in both the POSS-I and POSS-II images, must both have been merged with another bright star in the 1960s, at the time when Luyten obtained second epoch images for his proper motion survey. Our SUPERBLINK software was specifically designed in part to address this particular problem of "merged" stellar images, and our results now indicate that we have successfully achieved our goal.

The absence of LSR0939+7821, LSR1120+1953, LSR1254+7002, LSR1359+2635, and LSR1602+0131 from the Luyten catalogs is more difficult to explain. All these stars are reasonably bright, and make for very obvious proper motion identification. These are true "misses", but there are so few of them overall that we can only emphasize the impressively high success rate that Luyten managed to achieve at high galactic latitudes for stars down to r=16.

6. Reduced proper motion diagrams and estimated stellar class

We have constructed reduced proper motion diagrams for all the stars recovered in our survey, by combining the USNO-B1.0 and 2MASS magnitudes with the proper motions measured with

SUPERBLINK. The reduced proper motion in the r band is defined as:

$$H_r \equiv r + 5 + 5\log\mu = M_r + 5\log v_t - 3.38,$$

where M_r is the absolute magnitude, and v_t the transverse velocity in km s^{-1}. Reduced proper motion diagrams are made by plotting the reduced proper motion against a color, such as H_r versus $b-i$. The resulting plot is akin to an HR diagram but with an extra scatter of the points due to the $5\log v_t$ term. White dwarfs are well separated from the red dwarfs on a reduced proper motion diagram, just as they would be on an HR diagram. The beneficial effect of the $5\log v_t$ term is to separate old disk and halo subdwarfs, which generally have larger v_t, from the young disk dwarfs. Hence reduced proper motion diagrams are an easy way to discriminate white dwarfs, halo subdwarfs, and disk dwarfs, in a sample of stars for which we only have proper motions and magnitudes.

We adopt two different reduced proper motion diagrams, each of which depends on the availability of either complete bri magnitudes from the USNO-B1.0 or K_s magnitudes from 2MASS. The (H_r,$r-K_s$) diagram was investigated by Salim & Gould (2002), and was found to be relatively efficient in discriminating between high proper motion dwarfs, subdwarfs, and white dwarf stars. To cover up for those stars too faint to show in the 2MASS survey, we also introduce here the (H_r,$b-i$) diagram, which is based solely on the POSS photographic magnitudes, obtained from the USNO-B1.0 catalog. The two reduced proper motion diagrams are somehow complementary. Faint blue stars, like the white dwarfs, often fail to show up on 2MASS images, but we can almost always obtain $b-i$ for them. On the other hand, very red faint stars, almost invariably show up in 2MASS (in available areas) and $r-K_s$ is readily obtained, but these stars often do not record on the POSS-II b plates, and so are lacking $b-i$ colors.

We plot both the (H_r,$r-K_s$) and (H_r,$b-i$) diagrams in Figure 7. The left panels show the diagrams for the recovered LHS stars, for which the appropriate magnitudes are available. The right panels show the diagrams for the new high proper motion stars found by SUPERBLINK. Dashed lines separate the loci of the three general types of objects that are discriminated in the reduced proper motion diagrams. The regions are labeled "wd" for the white dwarfs, "sd" for the subdwarfs or halo dwarfs, and "d" for the disk dwarfs. The boundaries between the three regions are somewhat arbitrary, as there always is a significant scatter of data points in reduced proper motion diagrams. For the (H_r,$r-K_s$) diagram, we use the limits defined by Salim & Gould (2002). To guide the tracing of the boundaries in the (H_r,$b-i$) diagram, we have separately plotted on this diagram the stars that fell in each of the regions in the (H_r,$r-K_s$) diagram, and for which both $r-K_s$ and $b-i$ was available.

We find the (H_r,$b-i$) diagram to be just as efficient as (H_r,$r-K_s$) in discriminating between white dwarfs and main sequence stars. On the other hand, the red dwarfs and subdwarfs are not as clearly separated in (H_r,$b-i$) as they are in (H_r,$r-K_s$). There appears to be a larger scatter in H_r for a given value of $b-i$ than there is for a given value of ($r-K_s$). This is possibly due to the larger instrumental errors in $b-i$, but may also reflect an actual intrinsic scatter in the $b-i$ colors

of red dwarfs and subdwarfs of a given luminosity, which could be the result e.g. of atmospheric activity in some of the stars.

We have determined stellar classes for all but one of the new high proper motion stars listed in Table 2. These stars are featured in at least one of the reduced proper motion diagrams. Several stars show up in both, and their position on the (H_r,$r - K_s$) diagram was generally consistent with their position on the (H_r,$b - i$) diagram. However there were a number of cases in which the positions were conflicting, and for those we gave precedence to the (H_r,$r - K_s$) diagram, following our discussion above. Individual stellar classes are included in Table 2. One should keep in mind that the classes are only indicative, and that spectroscopy is required to confirm the class of a object. Stellar classes determined from the reduced proper motion diagram are however useful as a guide to follow-up observations.

Figure 7 shows that a particularly significant result of our new survey is the addition of a significant number of stars with very large reduced proper motion. The number of known stars with $H_r > 21$ has been nearly doubled. Most of these objects are faint white dwarfs and subdwarfs. Follow-up observations of these stars could lead to significant advances in our knowledge of old white dwarfs and low-mass subdwarfs.

7. Conclusions

Our semi-automated survey for high proper motion in the northern sky, using the SUPERBLINK software, has been expanded and now covers over 97% of the sky north of $\delta = 0.0°$. In Paper I, we had reported the discovery of 138 new northern ($\delta = 0.0°$) stars with proper motions $0.5 < \mu < 2.0 = ''$ yr^{-1} at low galactic latitudes ($|b| < 25$). To this, we now add 57 new high proper motion stars at high galactic latitudes ($|b| > 25$). Our survey now includes 1797 northern stars with $0.5 < \mu < 2.0 = ''$ yr^{-1}, all in the magnitude range $7 < r < 20$. Most objects are rediscoveries of stars listed in the LHS and NLTT catalogs. Our extremely high recovery rate ($> 99.5\%$) of LHS and NLTT stars in the range $11 < r < 19$ suggest that our new survey has a very high completeness level in that magnitude range.

The SUPERBLINK software did not recover any star fainter than $r = 20$ which is the magnitude limit of the POSS-I plates, used as our first epoch. The efficiency of SUPERBLINK was also shown to be limited for brighter stars ($r < 11$), and nil for stars brighter than $r = 7$. This however, is of little consequence since the vast majority of $r < 11$ stars on the sky have already had their proper motions measured with the HIPPARCOS satellite. A combination of the bright high proper motion stars listed in the Tycho-2 catalog (Hog *et al.* 2000) with our own list of objects should yield a very nearly complete, and most accurate list of northern high proper motion stars with $0.5 < \mu < 2.0 = ''$ yr^{-1} down to magnitude $r = 19$.

We have directly determined, once and for all, the completeness of the LHS catalogue for the northern sky. Overall, Luyten's census of stars with proper motions in the range $0.5 < \mu < 2.0 = ''$

yr^{-1} was a little less than 90% complete for stars down to $r = 19$. However, his survey was apparently complete down to $r = 13$, but significantly incomplete at fainter magnitudes. We hope to have now settled the debate about the completeness of the LHS catalog. Our survey now supersedes the Luyten proper motion surveys, at least for the northern sky.

Reduced proper motion diagrams show that the newly discovered high proper motion stars are a mix of faint and probably nearby disk dwarfs, faint halo dwarfs or subdwarfs, and faint white dwarfs. While overall our survey added only 10% new objects to the census of stars with proper motions $\mu > 0.5''\ \mathrm{yr}^{-1}$, this contribution is very significant because most of the new stars are faint, low luminosity objects. In particular, the census of faint high proper motion white dwarfs and subdwarfs has been nearly doubled. We are currently working on a spectroscopic follow-up program for the high proper motion stars found in our survey. Spectral classification for most of the stars reported in this paper will be presented in Lépine *et al.* (2003, in preparation).

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The data mining required for this work has been made possible with the use of the SIMBAD astronomical database and VIZIER astronomical catalogs service, both maintained and operated by the Centre de Données Astronomiques de Strasbourg (http://cdsweb.u-strasbg.fr/).

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A. Finder charts

Finder charts of high proper motion stars are generated as a by-product of the SUPERBLINK software. We present in Figures 8a-8d finder charts for all the new, high proper motion stars presented in this paper and listed in Table1. All the charts consist of pairs of $4.25' \times 4.25'$ images showing the local field at two different epochs. The name of the star is indicated in the center just below the chart, and corresponds to the name given in Table 1. To the left is the POSS-I field, with the epoch of the field noted in the lower left corner (typically in the 1953-1955 range). To the right is the modified POSS-II field which has been shifted, rotated, and degraded in such a way that it matches the quality and aspect of the POSS-I image. The epoch of the POSS-II field is noted on the lower right corner. High proper motion stars are identified with circles centered on their positions at the epoch on the plate.

The charts are oriented in the local X-Y coordinate system of the POSS-I image; the POSS-II image has been remapped on the POSS-I grid. This means that north is generally up and east left, but the fields might appear rotated by a small angle for high declination objects. Sometimes a part of the field is missing: this is an artifact of the code. SUPERBLINK works on $17' \times 17'$ DSS subfields. If a high proper motion star is identified near the edge of that subfield, the output chart will be truncated. Similar finder charts are automatically generated for every single object identified by the code, and we are currently building a large electronic catalog of two-epoch finder charts.

Table 1. LSR stars not in the Luyten catalogs, but reported elsewhere in the literature

Star	α(J2000)	δ(J2000)	$\mu('' \ \mathrm{yr}^{-1})$	$pma(^\circ)$	b[a]	r	i	J[b]	H	K_s	ref[c]
LSR1000+3155	10 00 50.70	+31 55 49.4	0.511	231.9	17.0	14.9	12.0	10.26	9.64	9.27	G00a
LSR1311+2923	13 11 46.92	+29 23 52.5	0.505	312.2	19.1	17.7	17.9	.	.	.	C02
LSR1403+3007	14 03 22.20	+30 07 56.7	0.796	273.7	20.9	18.7	15.2	12.68	12.00	11.60	G00b
LSR1425+7102	14 25 04.81	+71 02 10.4	0.635	254.7	20.7	18.6	16.1	14.77	14.40	14.33	L03
LSR1524+2925	15 24 24.73	+29 25 31.6	0.626	184.8	20.3	16.6	13.3	11.21	10.53	10.15	R02
LSR1530+5608A	15 30 50.32	+56 08 43.5	0.545	298.9	19.4	17.5	16.0	15.19	14.57	14.32	M00
LSR1530+5608B	15 30 49.99	+56 08 50.1	0.515	298.5	20.1	17.8	16.3	15.47	14.93	14.76	M00
LSR1615+3151	16 15 09.98	+31 51 47.1	0.756	179.4	16.3	14.1	11.4	10.34	9.85	9.55	S88

[a]Photographic bri magnitudes from the USNO-B1.0 catalog.

[b]Infrared JHK_s magnitudes from the 2MASS All-Sky Point Source Catalog.

[c]Reference code: C02 = Carollo *et al.* (2002), G00a = Gizis *et al.* (2000a), G00b = Gizis *et al.* (2000a), L03 = Lépine, Shara, & Rich (2003), G97 = Gizis *et al.* (1997), R02 = Reid *et al.* (2002), M00 = Monet *et al.* (2000), S88 = Sanduleak & Pesch (1988)

Table 2. LSR stars not in the Luyten catalogs, and reported here for the first time.

Star	α(J2000)	δ(J2000)	μ ($''$ yr^{-1})	*pma* (°)	b[a]	r	i	J[b]	H	K_s	class
LSR0018+2853	00 18 06.48	+28 53 27.9	0.534	89.2	20.9	19.2	17.7	16.19	15.62	15.49	sd
LSR0053+2054	00 53 17.64	+20 54 45.4	0.559	92.1	20.2	18.3	15.5	13.50	12.94	12.69	d
LSR0101+3521	01 01 27.32	+35 21 53.9	0.606	92.2	20.1	18.8	16.5	15.59	15.22	14.88	sd
LSR0150+0900	01 50 36.18	+09 00 22.9	0.578	196.6	19.4	16.3	14.6	13.61	13.15	12.87	sd
LSR0302+0021	03 02 28.76	+00 21 43.5	0.504	146.1	20.1	17.5	15.8	14.77	14.12	14.03	sd
LSR0328+1129	03 28 34.58	+11 29 52.4	0.599	64.7	21.6	18.9	15.2	12.46	11.78	11.33	d
LSR0804+6153	08 04 05.84	+61 53 33.4	0.635	184.6	21.3	18.8	15.2	12.74	11.93	11.45	d
LSR0822+1700	08 22 33.78	+17 00 20.1	0.605	143.5	···	18.7	17.2	15.72	15.52	15.62	sd
LSR0833+3706	08 33 03.17	+37 06 08.4	0.625	213.4	19.5	17.9	14.8	12.28	11.63	11.23	d
LSR0836+2432	08 36 18.04	+24 32 56.3	0.542	154.3	20.1	19.0	18.1	···	···	···	wd
LSR0837+7037	08 37 18.03	+70 37 33.8	0.816	173.2	18.1	16.4	14.0	12.73	12.25	11.97	d
LSR0848+0856	08 48 01.16	+08 56 48.3	0.702	196.3	15.4	13.6	12.4	11.28	10.73	10.50	sd
LSR0923+1817	09 23 32.43	+18 17 05.8	0.858	136.8	18.0	16.0	14.8	13.80	13.42	13.18	sd
LSR0939+7821	09 39 10.87	+78 21 29.2	0.987	231.2	18.3	15.6	12.8	11.73	11.26	10.97	d
LSR0959+1739	09 59 41.94	+17 39 20.4	0.541	162.3	17.0	14.8	13.1	12.22	11.72	11.50	sd
LSR0959+7533	09 59 55.31	+75 33 09.6	0.557	220.6	···	18.0	14.7	12.57	11.98	11.60	d
LSR1002+6108	10 02 25.78	+61 08 58.9	0.561	234.8	19.5	18.5	17.8	···	···	···	wd
LSR1002+6349	10 02 12.10	+63 49 26.1	0.554	252.0	20.8	18.7	15.5	12.90	12.36	11.98	d
LSR1005+3759	10 05 49.78	+37 59 03.3	0.517	249.2	19.2	16.5	13.1	12.00	11.44	11.10	d
LSR1033+2559	10 33 20.37	+25 59 22.3	0.754	139.5	17.7	15.6	12.9	11.80	11.24	10.93	d
LSR1044+1327	10 44 53.65	+13 27 57.5	0.527	253.4	20.3	18.8	18.6	···	···	···	wd
LSR1107+4855	11 07 31.38	+48 55 23.0	0.729	263.9	20.7	18.7	18.0	···	···	···	wd
LSR1118+0941	11 18 14.64	+09 41 13.7	0.508	179.0	20.1	(19.3)	17.4	15.92	15.38	15.25	sd
LSR1119+0820	11 19 46.47	+08 20 36.4	0.517	132.5	20.6	(18.7)	15.0	12.77	12.22	11.90	d
LSR1120+1953	11 20 27.61	+19 53 28.7	0.846	231.1	17.2	14.9	13.2	11.16	10.65	10.38	d
LSR1122+4809	11 22 29.51	+48 09 54.6	0.599	268.6	18.1	15.9	13.9	12.16	11.55	11.30	d
LSR1143+0413	11 43 51.38	+04 13 26.0	0.534	257.8	20.2	18.3	14.8	13.11	12.51	12.13	d
LSR1153+3414	11 53 48.70	+34 14 16.4	0.511	130.2	18.3	16.2	14.4	13.29	12.78	12.56	sd
LSR1204+3158	12 04 14.48	+31 58 05.0	0.571	264.5	20.4	18.9	···	15.54	14.97	14.65	sd
LSR1227+2512	12 27 42.21	+25 12 58.8	0.581	289.6	20.6	18.6	17.3	14.79	14.26	14.12	sd
LSR1254+7002	12 54 37.92	+70 02 49.2	0.861	249.7	···	14.9	13.6	12.99	12.48	12.25	sd
LSR1259+1956A	12 59 45.82	+19 56 58.2	0.501	291.2	20.2	17.9	14.8	13.45	12.95	12.73	d
LSR1259+1956B	12 59 48.36	+19 56 41.0	0.495	291.0	20.3	18.9	15.3	13.77	13.28	13.00	d
LSR1302+3339	13 02 52.41	+33 39 59.7	0.609	276.8	17.5	15.4	13.8	13.73	13.23	13.07	sd
LSR1305+1934	13 05 36.72	+19 34 57.4	0.558	337.3	19.8	16.8	13.8	12.13	11.51	11.14	d
LSR1334+3303	13 34 29.21	+33 03 04.0	0.649	267.3	19.8	17.3	14.3	12.50	11.93	11.61	d
LSR1340+1902	13 40 40.74	+19 02 22.2	0.912	209.3	19.7	16.8	14.5	···	···	···	d
LSR1359+2635	13 59 35.52	+26 35 31.6	0.628	248.8	18.0	15.3	12.5	11.27	10.75	10.47	d
LSR1421+4952	14 21 25.55	+49 52 02.5	0.602	264.7	16.9	15.3	13.3	13.02	12.47	12.30	sd
LSR1442+3255	14 42 06.56	+32 55 07.4	0.526	168.4	16.7	14.9	14.0	12.93	12.39	12.16	sd
LSR1448+6148	14 48 46.86	+61 48 02.5	0.976	170.9	20.6	17.9	15.9	14.84	14.53	14.01	sd
LSR1523+3152	15 23 40.67	+31 52 57.1	0.628	165.7	20.5	18.6	18.3	···	···	···	wd
LSR1537+6102	15 37 38.77	+61 02 46.4	0.555	279.4	19.1	16.9	15.3	14.51	14.11	13.94	sd
LSR1554+1639	15 54 00.21	+16 39 50.6	0.523	225.4	20.9	18.6	15.3	13.11	12.52	12.16	d
LSR1559+7313	15 59 34.78	+73 13 59.2	0.501	309.2	18.8	18.3	18.6	···	···	···	wd
LSR1601+5943	16 01 12.35	+59 43 25.6	0.502	168.6	19.3	17.7	17.8	···	···	···	wd
LSR1602+0131	16 02 41.71	+01 31 57.3	0.581	196.4	18.3	15.4	12.4	10.89	10.39	10.03	d
LSR1604+0904	16 04 19.09	+09 04 29.6	0.581	273.5	18.4	16.3	13.4	12.32	11.83	11.56	d

Table 2—Continued

Star	α(J2000)	δ(J2000)	μ (″ yr^{-1})	*pma* (°)	b[a]	r	i	J[b]	H	K_s	class
LSR1641+2449	16 41 23.86	+24 49 44.0	0.650	255.1	20.8	17.9	16.9	15.36	14.98	14.99	sd
LSR1703+5910	17 03 14.25	+59 10 48.6	0.571	147.8	19.8	17.7	14.8	12.81	12.15	11.86	d
LSR1746+6953	17 46 49.03	+69 53 26.9	0.538	198.9	17.4	14.6	13.9	12.79	12.26	12.06	sd
LSR1940+8348	19 40 08.59	+83 48 58.3	0.936	243.5	18.7	17.5	17.2	16.65	16.24	16.96	wd
LSR2204+1505	22 04 21.50	+15 05 52.0	0.816	52.1	16.8	14.7	12.2	10.87	10.31	9.98	d
LSR2222+1221	22 22 33.76	+12 21 43.0	0.728	74.9	20.0	16.5	17.5	···	···	···	sd
LSR2223+1602	22 23 21.86	+16 02 09.6	0.635	152.2	20.3	18.5	15.0	14.10	13.58	13.29	d
LSR2312+1532	23 12 39.75	+15 32 38.5	0.564	101.1	20.6	18.6	15.5	13.32	12.73	12.38	d
LSR2338+3332	23 38 26.13	+33 32 50.6	0.639	165.6	···	(19.1)	···	···	···	···	–

[a]Photographic *bri* magnitudes from the USNO-B1.0 catalog. Values shown in parenthesis are magnitude estimates provided by the SUPERBLINK software in the absence of a corresponding value in the USNO-B1.0 catalog.

[b]Infrared JHK_s magnitudes from the 2MASS All-Sky Point Source Catalog.

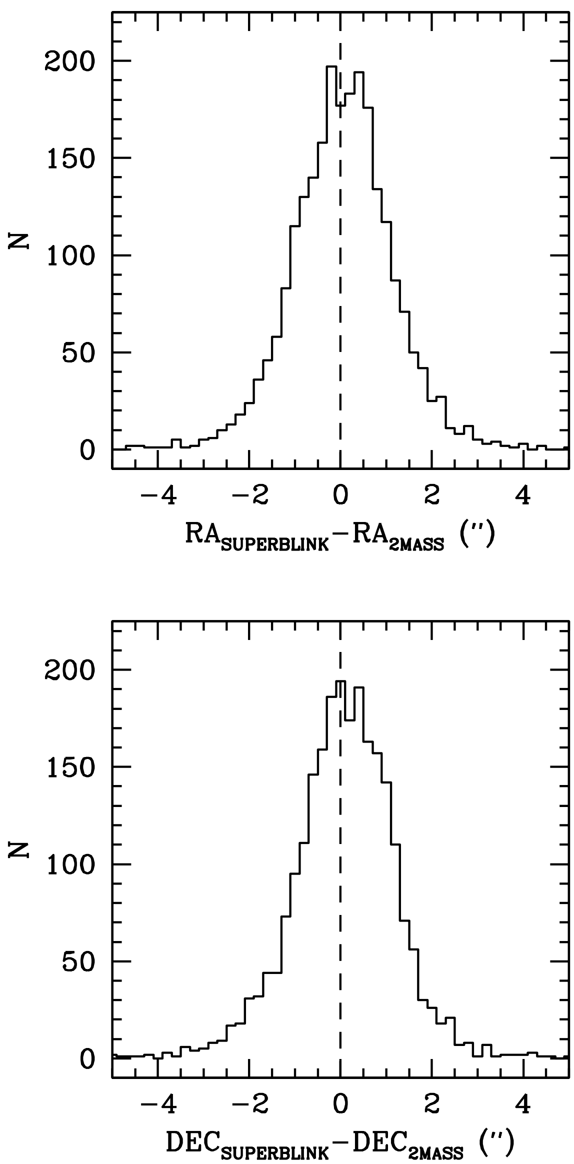

Fig. 1.— Difference between the positions of 1754 high proper motion stars given by our SUPERBLINK software with the positions of the same stars in the 2MASS All-Sky Point Source Catalog.

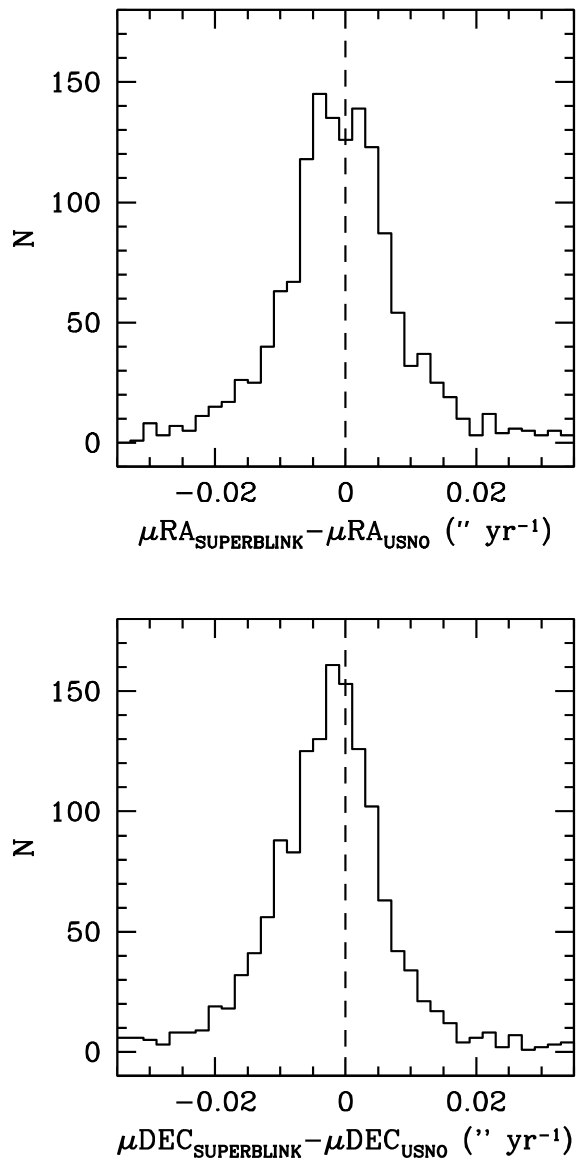

Fig. 2.— Difference in the proper motions measured by SUPERBLINK and those listed for the same stars recovered in the USNO-B1.0 catalog. The statistical distribution is shown separately for proper motions in RA (top) and DEC (bottom). Proper motion errors from SUPERBLINK are estimated to be $\pm 0.01'' \text{ yr}^{-1}$ in both RA and DEC, consistent with the distribution shown here. Estimated proper motions in the USNO-B1.0 catalog are generally $\pm 0.005'' \text{ yr}^{-1}$, although much larger errors exist for a significant fraction ($\sim 15\%$) of the stars, as evidenced here by the broad "wings" of the distribution.

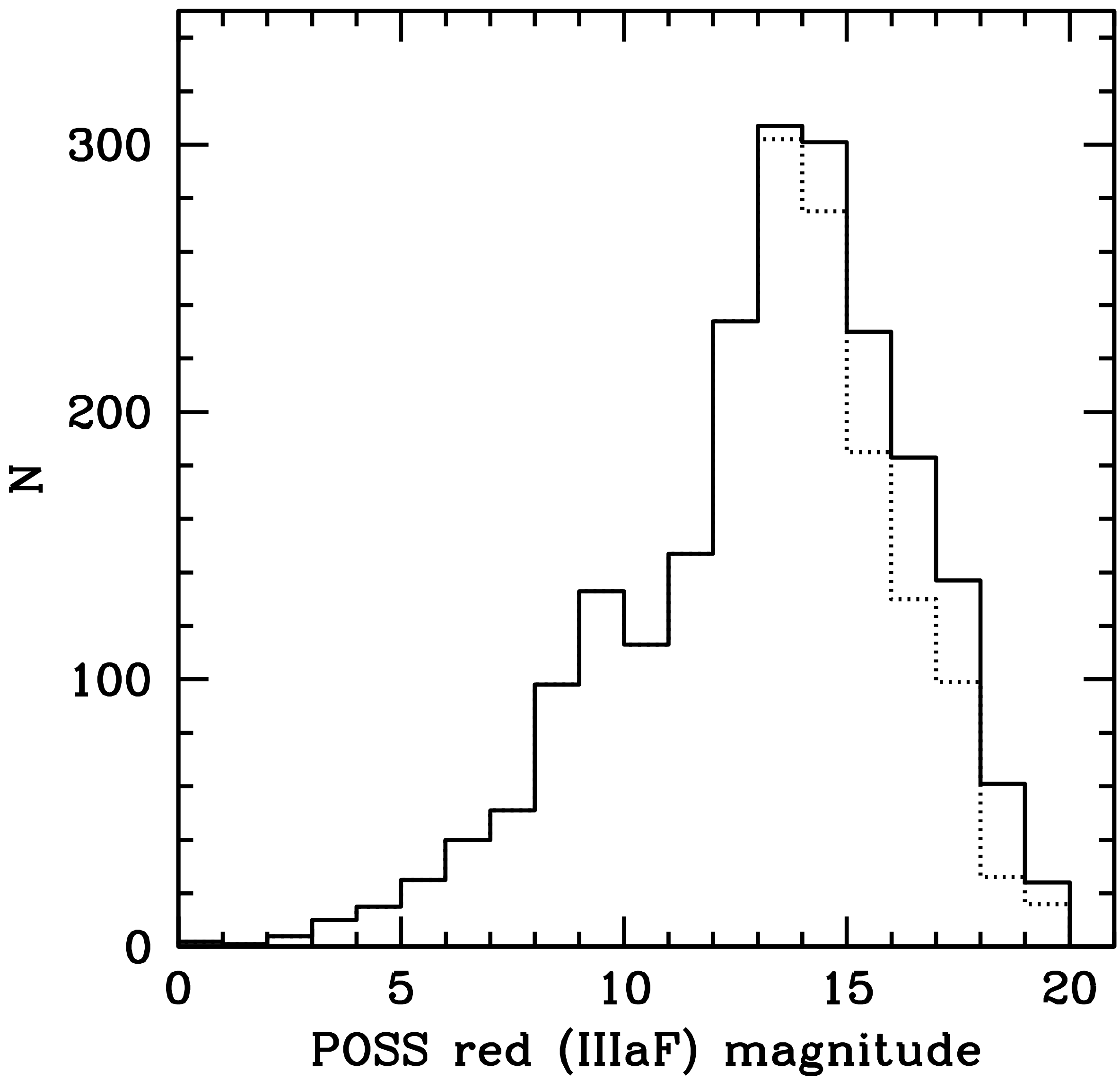

Fig. 3.— Updated distribution of northern stars with proper motions $0.5 < \mu < 2.0'' \text{ yr}^{-1}$ as a function of the photographic red (IIIaf) magnitude (full line). The previous distribution, based on LHS catalog stars, is shown for comparison (dotted line).

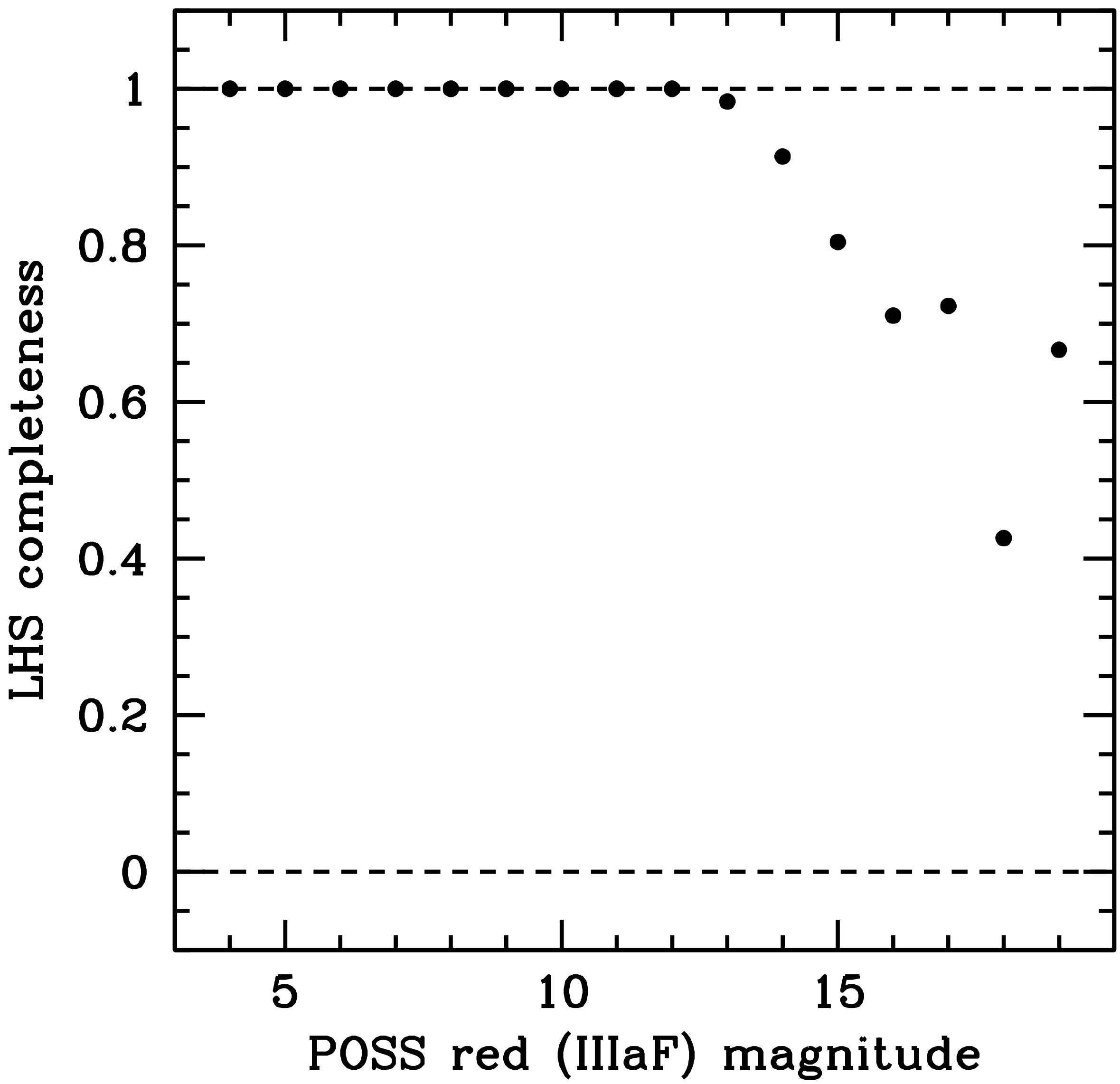

Fig. 4.— Measured completeness of the LHS catalog in the northern sky, as a function of photographic red (IIIaF) magnitude, for stars with proper motion $0.5 < \mu < 2.0''$ yr^{-1}. The LHS catalog was apparently complete for stars brighter than r=13, but its completeness dropped steadily at fainter magnitudes, falling below 50% at $r = 18$. Our new survey now considerably increases the completeness of the high proper motion census in that range.

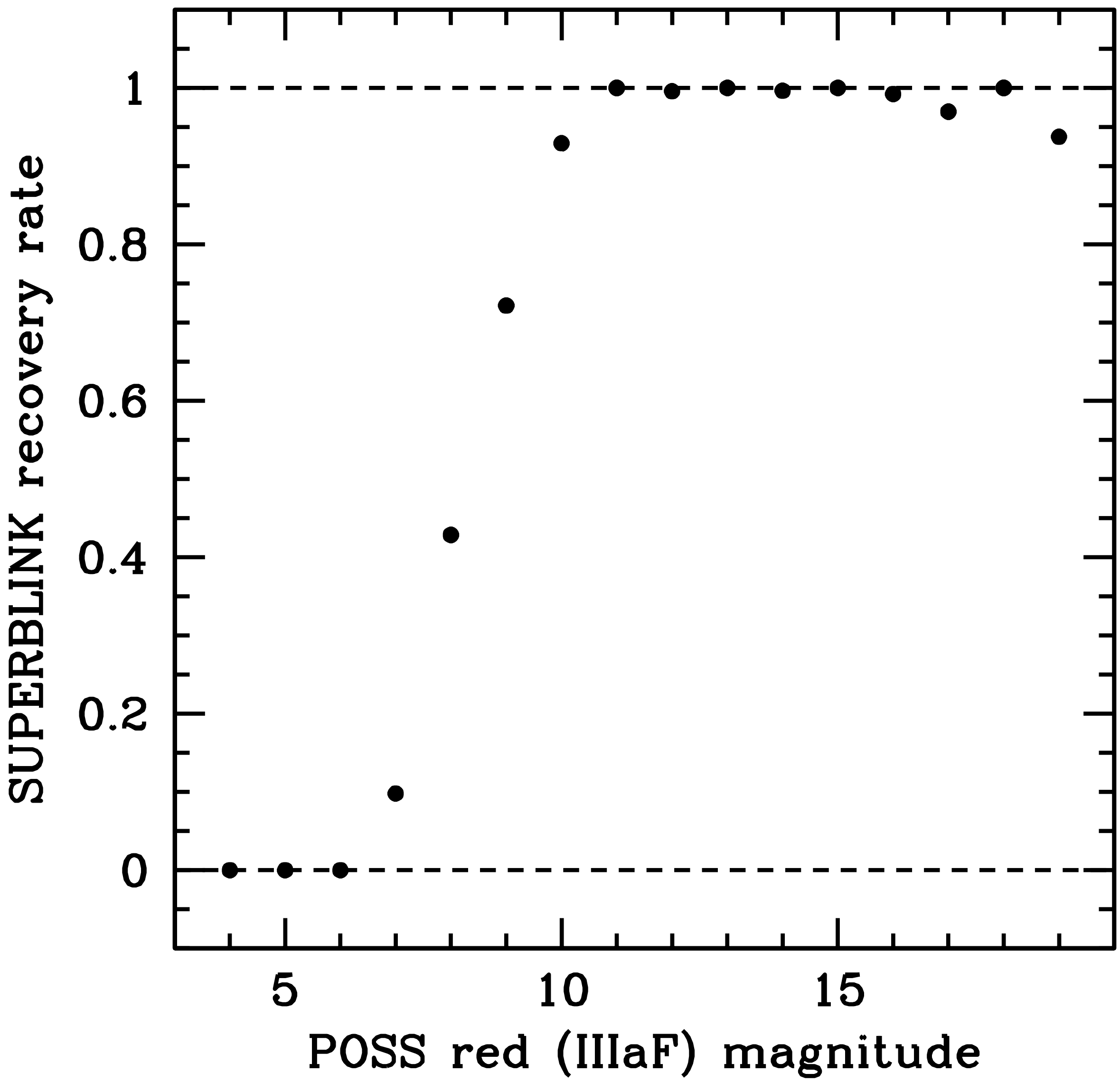

Fig. 5.— Recovery rate of LHS stars with proper motions ($0.5 < \mu < 2.0''$ yr^{-1}) by the SUPERBLINK software, as a function of the photographic red (IIIaF) magnitude. While SUPERBLINK is relatively inefficient in identifying very bright ($r < 10$) high proper motion stars, it is remarkably efficient for fainter stars, down to $r = 19$. Overall, more than 99.5% of the faint ($11 < r < 19$) LHS stars with proper motions $0.5 < \mu < 2.0''$ yr^{-1}, have been recovered by SUPERBLINK in the area covered by our survey.

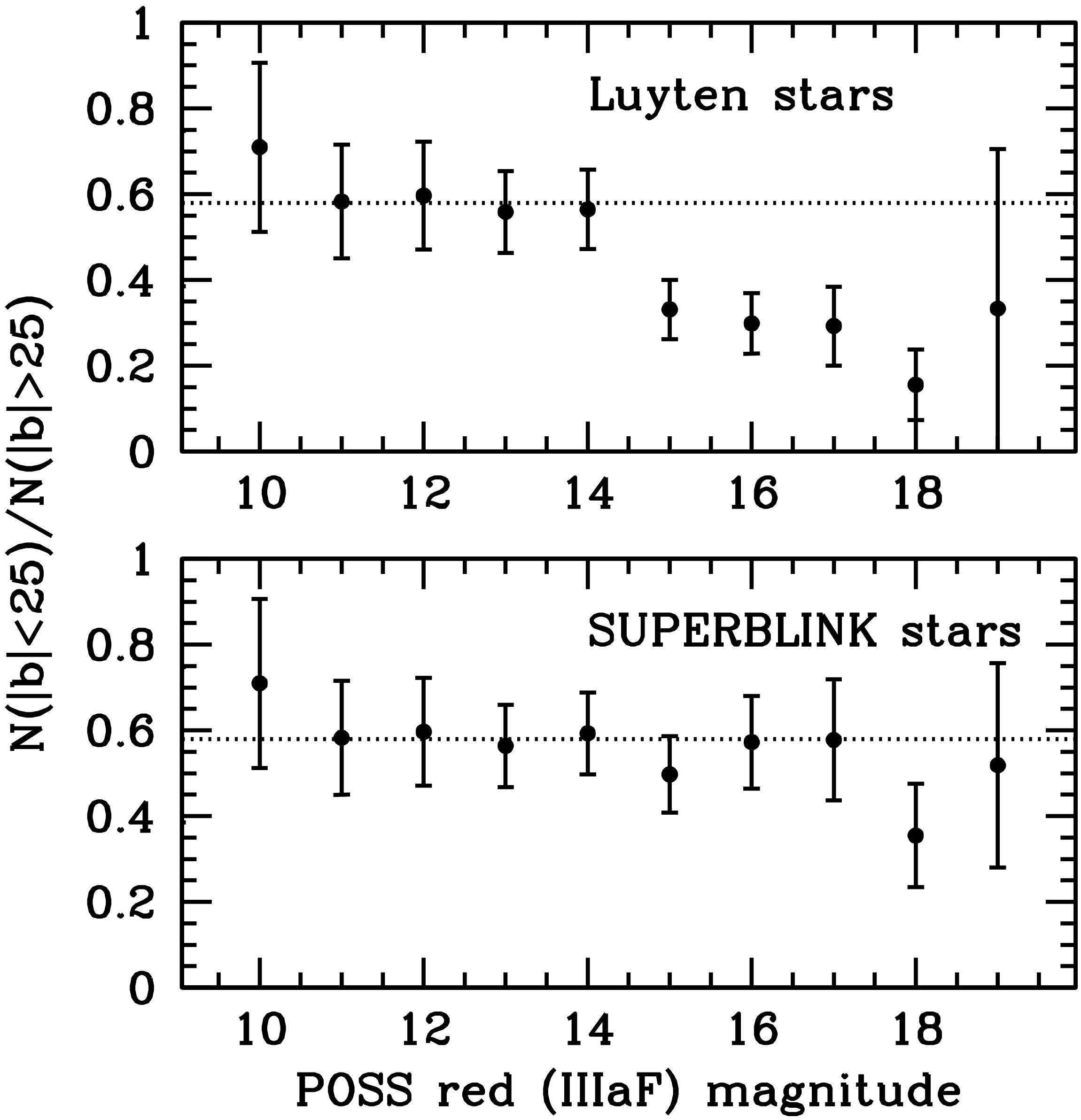

Fig. 6.— Ratio between the number of high proper motion stars found at low galactic latitudes ($|b| < 25.0$) and the number of high proper motion stars found at high galactic latitudes ($|b| > 25.0$), for the whole northern sky. The ratio is plotted separately for each magnitude bin between $r = 10$ and $r = 19$. The ratio is expected to be independent on the magnitude. This clearly shows the Luyten survey (top) to be significantly incomplete at $|b| < 25.0$, for stars $r = 15$ or fainter. Our own survey (bottom), shows evidence for significant incompleteness only for $r = 18$ stars.

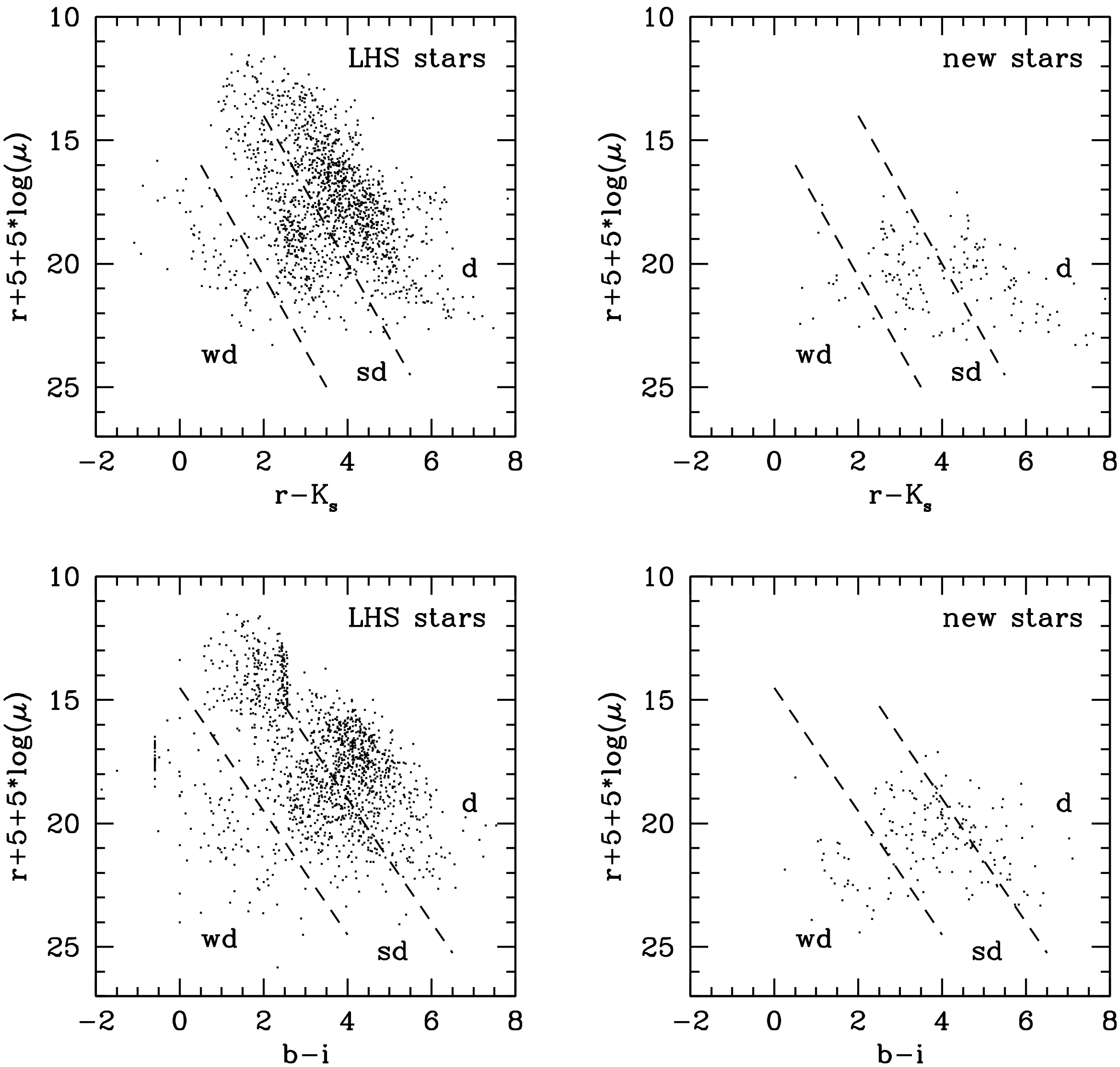

Fig. 7.— Reduced proper motion diagram for the high proper motion stars recovered by SUPERBLINK in high Galactic latitude fields. Left panels: star previously listed in the LHS and/or NLTT catalog. Right panels: new stars. Upper panels show the diagrams built with the $r - K_s$ color term, and include only those stars which have a counterpart in the 2MASS All-Sky Point Source Catalog. Bottom panels are built with the $b - i$ color term, and include all stars for which both a b and i magnitude was found in the USNO-B1.0 catalog. Dashed lines delimitate the region typically occupied by dwarf disk stars (d), subdwarf halo stars (sd), and white dwarfs (wd).

Fig. 8.— Finding charts for the new high proper motion stars discovered in our survey, as listed in Tables 1 and 2.

Fig. 9.— Finding charts for the new high proper motion stars discovered in our survey (continued).

Fig. 10.— Finding charts for the new high proper motion stars discovered in our survey (continued).

Fig. 11.— Finding charts for the new high proper motion stars discovered in our survey (continued).